Energis: Interactive Visualization Tool for Resource Usage Monitoring on Campus

Patsamon Boonchai
Dept. of Computer Engineering
Faculty of Engineering
Chiang Mai University
Chiang Mai 50200, THAILAND
patsamon_b@cmu.ac.th

Santi Phithakkitnukoon*
Dept. of Computer Engineering, and Excellence Center in Infrastructure Technology and Transportation Engineering, Faculty of Engineering,
Chiang Mai University
Chiang Mai 50200, THAILAND
santi@eng.cmu.ac.th

Pattarawit Jaiban
Dept. of Computer Engineering
Faculty of Engineering
Chiang Mai University
Chiang Mai 50200, THAILAND
pattarawit.jaiban@cmu.ac.th

Navadon Khunlertgit*
Dept. of Computer Engineering
Faculty of Engineering
and Biomedical Engineering Institute
Chiang Mai University
Chiang Mai 50200, THAILAND
navadon.k@cmu.ac.th

*Corresponding author

UbiComp/ISWC '18 Adjunct, October 8–12, 2018, Singapore, Singapore

ACM ISBN 978-1-4503-5966-5/18/10...$15.00
https://doi.org/10.1145/3267305.3274158

Abstract
This paper presents an interactive visualization tool for resource usage monitoring. This paper discusses the developing processes and focuses on implementation techniques for data preparation and visualization. The web application called *Energis* is developed as the first prototype. It features interactive 3D graphical map with numerical and animated infographics. It is designed to enable real-time user-to-user data sharing. A user experience study is conducted in order to evaluate the potential usage of the tool. The preliminary results from a standardized questionnaire show that the voluntary participants rate the application based on their hands-on experience at a consistently high level. With the availability of meter data providers, the tool can be utilized in location-based management to understand resource usage in both temporal and spatial domains.

Author Keywords
Visualization tool; Resource usage; Energy usage; Web application

ACM Classification Keywords
H.5.m [Information interfaces and presentation (e.g., HCI)]: Miscellaneous

Introduction

Visualization of resource usage plays a vital role in planning and analyzing. It could be of various kind of applications including real-time consumption monitoring, recorded information review, pattern analysis, and trend prediction. These applications are often used in designing or refining management strategies based on behaviors of users.

In this paper, we present an interactive tool that connects resource usage information such as meter data providers with urban planners and designers. Our work can be viewed as Platform as a Service (PaaS) with the goal of being a resource usage visualization hub. We aim at helping understand the characteristics of the resource usage and investigating geographical and dynamic aspects for area analysis and planning.

As a good starting point, we utilize the publicly available energy usage data. We develop a prototype web application called *Energis*, which allows the user to interactively monitor the energy usage on campus. We conduct a user experience study and discuss the potentials of the application.

Related Work

The design requirements for energy consumption visualization have been studied in [6] and [7]. These works collected evidence from other works of literature and listed the recommendations to achieve the goals. The following functional and non-functional requirements are the topics that should be taken into account.

- Providing real-time consumption data using interesting visualization technology has been proven to improve user interface engagement.
- The tool should provide disaggregation of data in which information regarding individual appliance could be provided and users to freely observe what they are interested in.
- Cross-platform application is recommended for exposure to a larger number of users.
- The tool should be available online to ensure accessibility
- The system should have an ability to scale in order to accommodate large information. The system should be designed suitable for all roles of user, for example, end-users and energy managers.

Concerning data transfer and storage, the cloud-based model has been shown to be the best candidate for asynchronous data exchange [9].

Visualization of real-time energy consumption has been shown to be one of the potential keys to reduce energy consumption. It can make hidden information visible and more readily understandable to end users. Data-driven animations could offer numerous potential benefits to society such as raising conservation behavior and support of good environmental management [3].

To move beyond the state-of-the-art and to contribute to this field of knowledge, *Energis* provides an online platform or PaaS for energy usage monitoring that supports different types of energy usage data on campus, unlike other existing visualization tools that are specific and limited to one particular type of data, such as [5][1][8][4].

Prototype Development and Implementation

Here we describe our prototype development separated into front-end and back-end developments where each deals with different components. As energy consumption data is a key in this development, we describe our data sources and how to pre-process them. Our implementation is described through a live demonstration recorded in a video. As for this first prototype, the energy usage on the main campus of the Chiang Mai University is used as a case study in this paper.

Front-end Development

The main user interface of the prototype is the interactive data visualizer. We make use multiple JavaScript libraries for implementing interactive diagrams. We utilize p5.js (https://p5js.org) for drawing the 3D model of the campus buildings and p5.EasyCam.js (https://github.com/diwi/p5.EasyCam) for controlling and interacting with the 3D model. Figure 1 shows the login page of the *Energis* where the user can log in using Google account or sign in as a guess. Once the user logs in, the tool will then ask to user to select the dates on which the energy usage is to be visualized and analyzed, as shown in Fig. 2. Figure 3 shows the main user interface, the interactive 3D visualization of resource usage, where the different color tones (from green to red) represent the levels of resource usage. The user can change the view of the 3D model including rotation and zoom-in/out by dragging and scrolling. The user can also view the instant numerical information of each location (i.e., room) by clicking on the 3D model. Via the top menu, the user can select to view graphs of basic statistics or go back to the previous page. We use Chart.js (https://www.chartjs.org) for displaying hourly resource usage information. The user can see basic charts of overall usage and usage per unit area (Figure 4 and 5).

Back-end development

Backend as a service (BaaS) model is being used in developing the prototype. We link our prototype to backend cloud storage and APIs provided by backend applications. The

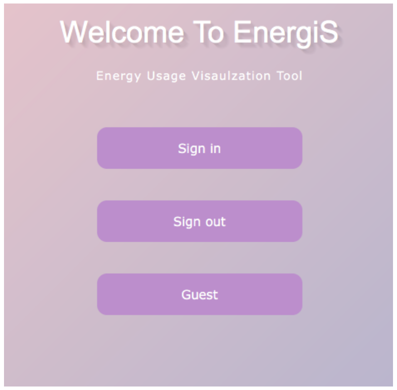

Figure 1: Login page of *Energis*

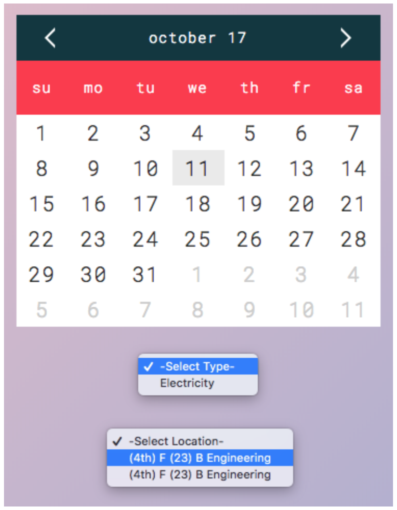

Figure 2: User can select the dates on which the energy usage is to be visualized and analyzed.

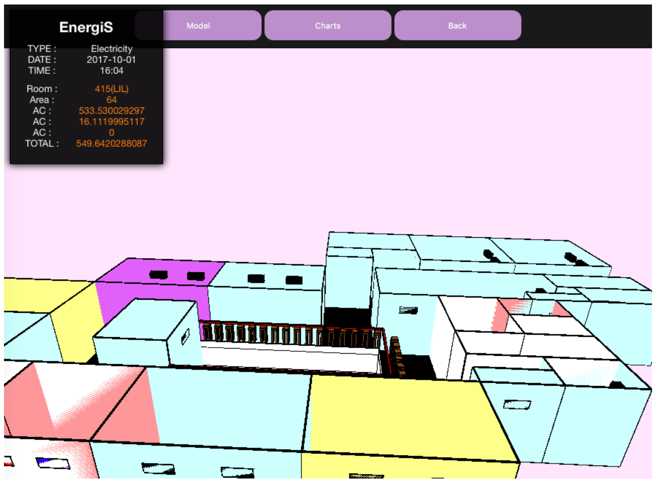

Figure 3: A snapshot of the interactive 3D visualization of resource usage.

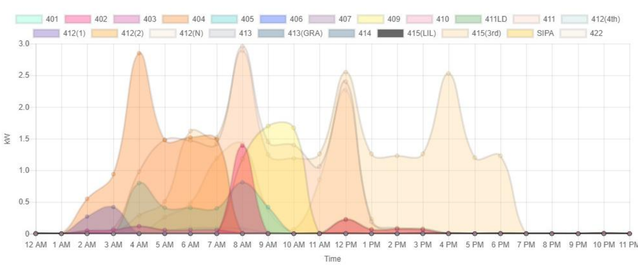

Figure 4: Hourly resource usage of selected location on specific date.

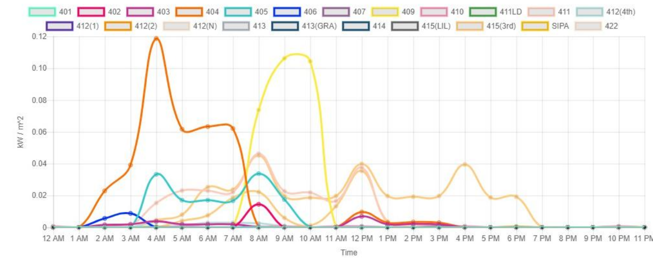

Figure 5: Hourly resource usage per unit area of selected location on specific date.

benefits of using BaaS is that it is server-less, high secured, real-time, and scalable. In this work, we use Google Firebase (https://firebase.google.com) as our backend. Google Firebase Realtime Database is used to store all data and Google Firebase Hosting is used to host the prototype web application. In addition to database and storage, integration with Google account allows user to store, manage, and share their own data.

Data Sources and Pre-processing

We use both real data and synthetic data as initial inputs of the prototype. We acquire real data from public air conditioner power usage information provided by the Learning Inventions Laboratory, Department of Computer Engineering, Chiang Mai University (https://lilcmu.github.io/cpe_energy/index.html). The data is in the comma separated values (CSV) format. We reduce the file size by removing redundant information in some columns such as location, type, and date. If there are duplicates, only the information of the first row is preserved. (see example in Figure 6). We also generate synthetic data to test our prototype by randomly duplicating and sampling the real data to the missing dates and times.

```
Location,Type,Date,id,Time,Value
1060000,Water,10/9/2017,1,0:00,202.32
,,,1,0:27,202.32
,,,1,0:53,202.32
,,,1,1:20,202.32
,,,1,1:47,202.32
,,,1,2:13,202.32
,,,1,2:40,202.32
,,,1,3:07,202.32
,,,1,3:34,202.32
,,,1,4:00,202.32
,,,1,4:27,202.32
```

Figure 6: Sample resource usage data in CSV format.

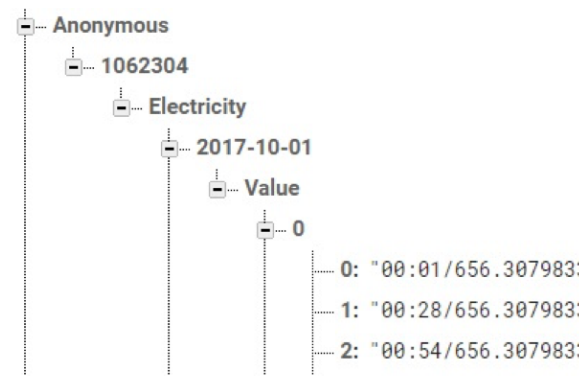

Figure 7: Sample resource usage data in JSON

Since Google Firebase Realtime Database is NoSQL database, we need to preprocess the data into JavaScript Object Notation (JSON) as shown in Figure 7 before uploading to Google Firebase Realtime Database. Finally, the processed JSON is used as the input of data visualizer.

Demonstration
The prototype has been posted on Google Firebase Hosting at https://energis-698b3.firebaseapp.com. A video clip showing how the prototype works is available at https://www.youtube.com/watch?v=Jpk2-pDaM0g.

User Experience Study

Methodolgy
We assess the prototype web application in terms of its functionality using standardized test for user experience. We adopt an evaluation questionnaire from the theory of four elements of user experience [2].

The questionnaire consists of a set of questions which all participants are asked to give a rating score according to their level of agreement regarding their experience with the prototype. The statements regarding the user experience are in the following list.

S1: It is useful.

S2: It is easy to use.

S3: It is interesting to use.

S4: It is fun and engaging.

The rating score is a 5-point Likert scale where 1 means the lowest agreement level and 5 means the highest agreement level. Space for additional comments and suggestions is also provided along with the four questions.

Experimental Setup
A pilot study is carried out in a voluntary participation. A total of 25 participants (14 men and 11 women) are included in this study. The participants are asked to perform multiple tasks in our prototype system and complete the questionnaire. The task scenarios are listed below.

	Mean	SD
S1	4.16	0.75
S2	4.00	0.91
S3	3.96	0.89
S4	3.56	1.00

Table 1: Results of user experience questionnaire.

- Display resource usage from specific location at a certain date and time
- Upload provided resource usage CSV files to the system and visualize through the system

Experimental Results
The overall average rating scores from the questionnaire are shown in Table 1. We can see that the overall highest rating score of 4.16 is from S1 regarding how useful the system is and lowest rating score of 3.56 is from S4 regarding how engaging the system is. For the variance of the response, the SD of rating score of S4 is the highest (1.00). This is because the interpretation of fun and engaging can be varied based on individual background.

We investigate user experience further by grouping participant responses into meaningful groups of respondents which are based on their gender, age, and occupation, respectively.

Table 2 shows average rating scores of male and female participants. The average rating scores from male participants are slightly higher than ones of female in S1-S3. We can interpret that male users have the better experience in terms of value (S1), usability (S2), and adoptability (S3).

	Male	Female
S1	4.29	4.00
S2	4.07	3.91
S3	4.07	3.82
S4	3.50	3.64

Table 2: Results of user experience questionnaire grouped by gender.

	<20	20-29	30-39	>39
S1	4.00	4.17	4.25	4.00
S2	4.00	4.11	3.75	3.00
S3	4.00	3.89	4.25	4.00
S4	4.50	3.44	3.75	3.00

Table 3: Results of user experience questionnaire grouped by age range.

Female participants find the system is more fun and engaging (S4).

To examine age-related differences in user experience, we sort the participants result by age range. There are 2 people who are under 20 years old, 18 people between 20-29 years old, 4 people between 30-39 years old, and 1 person more than 39 years old. Even though the majority age group of the participants is between 30-39 years old, we can still observe some age-related trends.

We can see from Table 3 that the participants who are under 20 years of age rate highest in terms of how engaging the system is (S4: 4.50). The participants in age group 20-29 years old find the system easy to use (S2) with the highest average rating score of 4.11. The participants who are in 30-39 age group highly agree that the system is useful

	G1	G2	G3
S1	4.22	4.00	4.00
S2	4.11	3.33	4.00
S3	3.89	4.00	4.25
S4	3.72	3.33	3.00

Table 4: Results of user experience questionnaire grouped by occupation.

(S1: 4.25) and interesting to use (S3: 4.25). The participants who are over 39 years old rate the system in aspects of usability (S2) and adoptability (S4) the same lowest average rating score of 3.00 as shown in the comments that they think that the system is not easy to use without a system manual.

We also investigate occupation-related differences in user experience. The participants are grouped into 3 different occupation groups that are as follows.

G1: student

G2: public sector (e.g. government)

G3: private sector (e.g. most businesses and individuals)

The numbers of people for groups G1, G2, and G3 are 18, 3, and 4, respectively. As shown in Table 4, the student participants (G1) give the highest rating score of 4.22, 4.11, and 3.72 reflecting on the system's usefulness (S1), ease of use (S2), and being fun and engaging (S4). The participants who are working in private sector (G3) rate highest in S3 asking if the system is interesting to use. Interestingly, the lowest rating score of S3 is from student participants.

We can also observe that the comments and suggestions given by the participants show the similar trends with the statistical results. One of the male participants who are in 30-39 age group and work in private sector gives comments, *"It is very useful. It could be used it to plan about resource usage. The system would be beneficial to the organization in many ways"*. One of the comments from the female participant who is a student under 20 years old is *"The system looks interesting and colorful"*. Male students in 20-29 age group share the same comment about utilizing interactive 3D model helps them get the picture of energy usage and the user interface is attractive.

Conclusion

This paper presents an interactive visualization tool for resource usage monitoring on campus called *Energis*. The tool is in the form of web application which is developed using online services and storage. The energy usage is visualized on an interactive 3D map of buildings on campus with numerical information and animated infographics. Unlike other existing visualization tools, which are specific and limited to one type of data, *Energis* offers a platform for visualizing and analyzing any kinds of resource usage data on campus – such tool has never existed before. We study the potential of the application model by a user experience study. Although this paper reports on the early stage development of the *Energis*, we still believe that the approach, methodology, and preliminary implementation of *Energis* can be beneficial for other researchers in the fields, and ultimately to the people who are involved in campus resource usage planning and management.

Acknowledgements

We would like to thank the Learning Inventions Laboratory, Department of Computer Engineering, Chiang Mai University for provision of their data. We also would like to thank

Prof. Dome Potikanond and Prof. Arnan Sipitakiat for their valuable comments and useful discussions. We appreciate all the volunteers who give the feedback and participate in our questionnaire.

References

[1] Adiporl Binthaisong, Jaruwan Srichan, and Santi Phithakkitnukoon. 2017. Wi-Crowd: Sensing and Visualizing Crowd on Campus Using Wi-fi Access Point Data. In *Proceedings of the 2017 ACM International Joint Conference on Pervasive and Ubiquitous Computing and Proceedings of the 2017 ACM International Symposium on Wearable Computers (UbiComp '17)*. ACM, New York, NY, USA, 441–447. DOI: http://dx.doi.org/10.1145/3123024.3124413

[2] Frank Guo. 2012. More Than Usability: The Four Elements of User Experience, UX matters. (April 2012). https://www.uxmatters.com/mt/archives/2012/04/more-than-usability-the-four-elements-of-user-experience-part-i.php

[3] Tiffany Grace Holmes. 2007. Eco-visualization. *Proceedings of the 6th ACM SIGCHI conference on Creativity and Cognition* (2007). DOI: http://dx.doi.org/10.1145/1254960.1254982

[4] Nuttapong Kaewnoi, Narida Suntiparadonkul, Santi Phithakkitnukoon, and Zbibniew Smoreda. 2016. Visualizing Mobile Phone Usage for Exploratory Analysis: A Case Study of Portugal. In *Proceedings of the 2016 ACM International Joint Conference on Pervasive and Ubiquitous Computing: Adjunct (UbiComp '16)*. ACM, New York, NY, USA, 1358–1362. DOI: http://dx.doi.org/10.1145/2968219.2968413

[5] Narumon Kunama, Mudtana Worapan, Santi Phithakkitnukoon, and Merkebe Demissie. 2017. GTFS-Viz: Tool for Preprocessing and Visualizing GTFS Data. In *Proceedings of the 2017 ACM International Joint Conference on Pervasive and Ubiquitous Computing and Proceedings of the 2017 ACM International Symposium on Wearable Computers (UbiComp '17)*. ACM, New York, NY, USA, 388–396. DOI: http://dx.doi.org/10.1145/3123024.3124415

[6] Latha Karthigaa Murugesan, Rashina Hoda, and Zoran Salcic. 2013. Investigating Visualization of Energy Consumption. *Proceedings of the 14th Annual ACM SIGCHI NZ conference on Computer-Human Interaction - CHINZ '13* (2013). DOI: http://dx.doi.org/10.1145/2542242.2542255

[7] Latha Karthigaa Murugesan, Rashina Hoda, and Zoran Salcic. 2014. Visualization of Electricity Consumption: Software Prototype through Literature Survey. *International Journal of Innovative Research in Science, Engineering and Technology* 3, 3 (March 2014), 2725–2729.

[8] Postsavee Prommaharaj, Santi Phithakkitnukoon, Marco Veloso, and Carlos Bento. 2016. Visualization Tool for Taxi Usage Analysis: A Case Study of Lisbon, Portugal. In *Proceedings of the 2016 ACM International Joint Conference on Pervasive and Ubiquitous Computing: Adjunct (UbiComp '16)*. ACM, New York, NY, USA, 1343–1348. DOI: http://dx.doi.org/10.1145/2968219.2968411

[9] Chi-Sheng Shih, Kuo-Hsiu Lee, Jyun-Jhe Chou, and Kwei-Jay Lin. 2017. Data-driven IoT applications design for smart city and smart buildings. In *2017 IEEE SmartWorld, Ubiquitous Intelligence Computing, Advanced Trusted Computed, Scalable Computing Communications, Cloud Big Data Computing, Internet of People and Smart City Innovation (SmartWorld/SCALCOM/UIC/ATC/CBDCom/IOP/SCI)*. 1–8. DOI: http://dx.doi.org/10.1109/UIC-ATC.2017.8397394